USASRDL Technical Report 2239

MEASUREMENTS OF WAVEFRONT DISTORTION AND THE ELECTRICAL PROPERTIES OF GROUND AT HIGH FREQUENCIES

by

Donn V. Campbell

December 1961

U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY

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ABSTRACT

The polarization and direction of the electromagnetic field, produced by a distant source of radiation, are affected by electrical ground properties, terrain contours, and vegetation. These effects have been measured along the axis of a 1.2-mile linear antenna array (ISCAN), presently under separate investigation. The method of evaluating the measurements is described and the results correlated with known features of the site.

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INTRODUCTION

During the investigation of a 1.2-mile linear receiving antenna array designed to operate in the 12 to 18 mc frequency range, it became apparent that terrain features, electrical ground properties, and vegetation affected the array performance. In an attempt to correlate these effects, the earth's conductivity and dielectric constant were measured by means of a rotatable receiving dipole which permits a point-by-point study of large land areas. Here we discuss the use of the dipole method in connection with the high-frequency measurements of ground properties.

PURPOSE

The purpose of this investigation was to obtain information on the electrical ground properties in the vicinity of an antenna array, and later, to attempt to correlate these properties with the performance of the antenna. We utilized the dipole method to determine the magnitude of the earth's conductivity and dielectric constant in evidence at the ISCAN site near La Plata, Maryland. Knowledge of these properties, which depend upon frequency, facilitates the interpretation of the array performance. In August 1961, we performed measurements using a frequency of 15.1 mc, nominally the mid-frequency of the array.

DISCUSSION

The Dipole Method of Polarization Parameter Measurement

For an earth of finite conductivity, the electric field of a vertically polarized wave is not perpendicular to the earth's surface, but is inclined in the direction of wave propagation producing elliptical rather than linear polarization. The dipole method described below was employed to measure two parameters which characterize the polarization ellipse (namely its forward tilt angle and axis ratio), and to provide measurement of the wavefront distortion caused by terrain non-uniformities and vegetation.

A 100-watt truck-mounted transmitter was used to energize a 15-foot whip antenna sited near the Potomac River Bridge, 6 miles from the ISCAN array on the perpendicular bisector of the array axis. The intervening terrain is mostly water so that any radiated horizontal field components are presumably eliminated before reaching the array site on the opposite shore. (See Figure 1)

The field of the transmitter was probed by means of the dipole at six locations close to the array axis. The selected locations were between elements number 1 and 2, 7 and 8, 12 and 13, 17 and 18, 21 and 22, and 23 and 24 on a line parallel to and 15 feet from the array axis on the side nearest the river.

The dipole or "probe" consisted of a battery-powered, narrow-band, AM receiver equipped with a carrier-level meter for visual observation of relative field strength. The receiver was mounted atop a 10-foot phenolic column supported by a heavy-duty tripod equipped for leveling. The dipole was attached directly to the receiver. The entire assembly is rotatable in azimuth and elevation by an operator below, who can observe on dials the relative field strength and azimuth and elevation angles. The receiver gain can also be controlled from the ground so that "on-scale" meter readings for both strong or weak signals can be obtained. The complete instrument is called the "Ground Constants Measuring Set" and was constructed in 1954 under contract to the Signal Corps.

The first step in the measuring procedure adopted makes use of the dipole as a direction finder. This dipole is alternately rotated in azimuth and elevation until an absolute null in response is observed on the meter, and the elevation E_0 and azimuth A_0 angles are recorded. The dipole is now normal to the incidence plane, and consequently A_0 is the apparent bearing of the target transmitting source. We often found that, in the La Plata measurements, the apparent bearing differed considerably from the true line-of-sight direction to the target source because of local wavefront distortion caused by reflections, refraction, ground slope, vegetation, etc.

The dipole is next rotated from the apparent bearing A_0 to the angle $A_0 + 90^\circ$, so that when rotated about its horizontal axis, it revolves in the plane of incidence of the oncoming wave. Again, using the null method, the dipole is revolved about its horizontal axis keeping its azimuth fixed at $A_0 + 90^\circ$ until the response is at a minimum. The tilt angle γ of the minor axis of the polarization ellipse is also the tilt angle of the dipole at this minimum response elevation, and the response measured is directly proportional to the amplitude of the minor axis b of the polarization ellipse. (See Figure 2) The receiver gain is adjusted to give nearly full-scale deflection of the meter.

Keeping the receiver gain fixed, we restore the dipole to the apparent bearing A_0. It is then revolved about its horizontal axis until we reach the same amplitude on the meter as measured for the minor-axis minimum. The major axis of the polarization ellipse is then inversely proportional to the sine of the elevation angle ψ thus obtained.

The axis ratio r of the polarization ellipse is calculated from

$$r \approx \frac{1}{\sin \psi \cos \gamma} . \qquad (1)$$

For the small tilt angles γ, evidenced in this investigation, the error introduced by measuring the projection of the ellipse on the vertical axis instead of measuring the major axis directly is negligible. This measuring procedure was successfully employed at La Plata in August 1961. Inaccuracy was minimized by extending this technique to include the well-known 180°-reversing method, or by plunging the dipole end-for-end and averaging the angles.

In general, the three polarization parameters accessible to measurement are the axis ratio r, tilt angle γ of the minor axis against the horizontal, and the ratio $|\rho|$ of the horizontal and vertical width. Two of these parameters are independent variables. The above procedure measures parameters r and γ.

For the purpose of calculating the earth's electrical properties by methods described below, it is necessary to know the ratio $|\rho|$ and the phase angle φ between the horizontal and vertical component. The amplitude ratio $|\rho|$ is calculated from the equation

$$|\rho| = \frac{1 + \frac{r-\frac{1}{r}}{r+\frac{1}{r}} \cos 2\tau}{\sqrt{1 - \left(\frac{r-\frac{1}{r}}{r+\frac{1}{r}}\right)^2 \cos^2 2\tau}} \tag{2}$$

where r is given by equation (1) and

$$\tau = 90 - \gamma. \tag{3}$$

To be consistent with the equations below, the phase angle between the horizontal and vertical component is called φ and is calculated from the equation

$$\varphi = \sin^{-1} \frac{r(1+|\rho|^2)}{|\rho|\ (1+r^2)} \tag{4}$$

using the numerical values for r and $|\rho|$.

This completes the description of the dipole method and its use in evaluating the polarization parameters φ and $|\rho|$.

The Relation of the Earth's Electrical Properties to the Polarization Parameters for Homogeneous Earth

According to Grosskopf and Vogt[2] the earth's electrical properties can be calculated by measuring two polarization parameters characterizing the elliptically polarized wave in the incidence plane as described above.

For a homogeneous, non-layer earth structure they show the equation of this polarization ellipse to be

$$E_{xo}^{\ 2} + |\rho|^2 E_{yo}^{\ 2} - 2|\rho| E_{xo} E_{yo} \cos \varphi = |\rho|^2 \sin^2\varphi \tag{5}$$

in which E_{xo} and E_{yo} are the horizontal and vertical components, respectively. Further, Grosskopf and Vogt have shown that φ and $|\rho|$ are dependent upon the earth's electrical properties according to the relations

$$\text{Tan } 2\varphi = \frac{2\sigma}{\varepsilon f} \quad (6)$$

and

$$|\rho| = \frac{1}{\sqrt[4]{\varepsilon^2 + \left(\frac{2\sigma}{f}\right)^2}} = \left| \frac{E_{xo}}{E_{yo}} \right| \quad (7)$$

in which σ and ε, respectively, are the earth's conductivity and dielectric constant expressed in electrostatic units (esu), and f is the frequency in cycles per second.

Because the above article[2] deals primarily in the earth's electrical properties at broadcast frequencies, the approximation below is permissible.

$$\frac{2\sigma}{f} >> \varepsilon.$$

In this case we may use two methods for evaluating σ: the wave-tilt or the axis-ratio method. However, at high frequencies and for finite conductivity, $|\rho|$ and φ vary strongly with ε. In view of this, both the wave tilt and axis ratio must be known in order to calculate φ and $|\rho|$.

Solution of equations (6) and (7) for the dielectric constant and conductivity results in

$$\varepsilon = \frac{\cos 2\varphi}{|\rho|^2} \text{, in esu} \quad (8)$$

and

$$\sigma = \frac{f}{2} \, \frac{\sin 2\varphi}{|\rho|^2} \text{, in esu} \quad (9)$$

where

$$1 \text{ esu} = \frac{1}{9} \times 10^{-20} \text{ emu.}$$

These equations are employed in this investigation and numerical values are given in Table 1.

Evaluation and Interpretation of Measurements

Grosskopf and Vogt[2] have pointed out that the phase angle φ gives an indication as to whether or not a material is homogeneous. They state that if $\varphi > 45^\circ$, it indicates that the earth's surface in the vicinity of the measuring equipment has a layer structure consisting of a dry over-surface and a good conducting under-layer. On the other hand, if $\varphi < 45^\circ$, then a homogeneous earth of lower conductivity is in evidence. They also state that in the case $\varphi < 45^\circ$, the theory of a layer-conductor admits the possibility of the existence of a good conducting-layer over a dry under-layer. We are concerned only with the effective conductivity.

As shown in Table 1, the conductivity varies over a seven-to-one range of ratios, with the largest being at the array end (23 and 24), and the smallest near the mid-point of the array (12 and 13). Except for the earth in the vicinity of elements number 7 and 8, and 12 and 13, it may be classified electrically as "fairly good." Between elements number 21 and 22, a layer earth-structure is certainly evident because $\varphi = 45.7^{\circ}$. Consideration of the effect of inaccuracies of the measurements indicates that the σ value calculated in this case may not be too reliable. The results at the remaining locations can be considered reasonably accurate.

Examination of Figure 1 reveals that between elements number 1 and 2, the ground slope and dipole inclination are negative and the apparent bearing is 15.3° to the left of the true bearing. On the other hand, between elements number 12 and 13, the opposite condition obtains where the dipole inclination for the null and the ground slope are positive, and the apparent bearing is 10.7° to the right of the true bearing. Although this evidence is meager, results seem to indicate that even a moderate ground slope appreciably alters the polarization.

It is probable that nearby vegetation and wooded areas are responsible for much of the observed wavefront distortion. This is almost certainly the case at the rear end of the array (element number 1) where the deviation from true bearing was inordinately large. The 100-foot wide clearance in dense woods extending from elements number 1 to 6 may act as a trough waveguide deforming the wavefront. In performing measurements between elements number 1 and 2, and 12 and 13, extreme care was needed to achieve a good null while searching for the apparent bearing. This condition may indicate the existence of a polarization ellipse parallel to the earth's surface. In the set-up between elements number 12 and 13, however, there was a nearly unobstructed path to the illuminating transmitter except for fairly dense woods to the right front of element number 12. Because of this geography, we expected only a slight distortion of the wavefront. However, it developed that a relatively large distortion was evident. Considering this, it appears that the ground slope has appreciable influence upon the wavefront, and this influence may occasionally even exceed that of the surrounding wooded areas.

CONCLUSION

The earth's conductivity varies from 3.48×10^{-14} emu to 23.8×10^{-14} emu along the array, and for the most part the earth may be classified electrically as "fairly good." Layer-earth structure is evidenced in the vicinity of elements number 21 and 22, and possibly near the end of the array. This layer-earth structure consists of a dry over-layer of earth with an under-layer which is probably water.

The wavefront distortion appears to be severe where the earth has considerable slope. The wavefront is also affected appreciably by vegetation and woods along the array.

ACKNOWLEDGEMENTS

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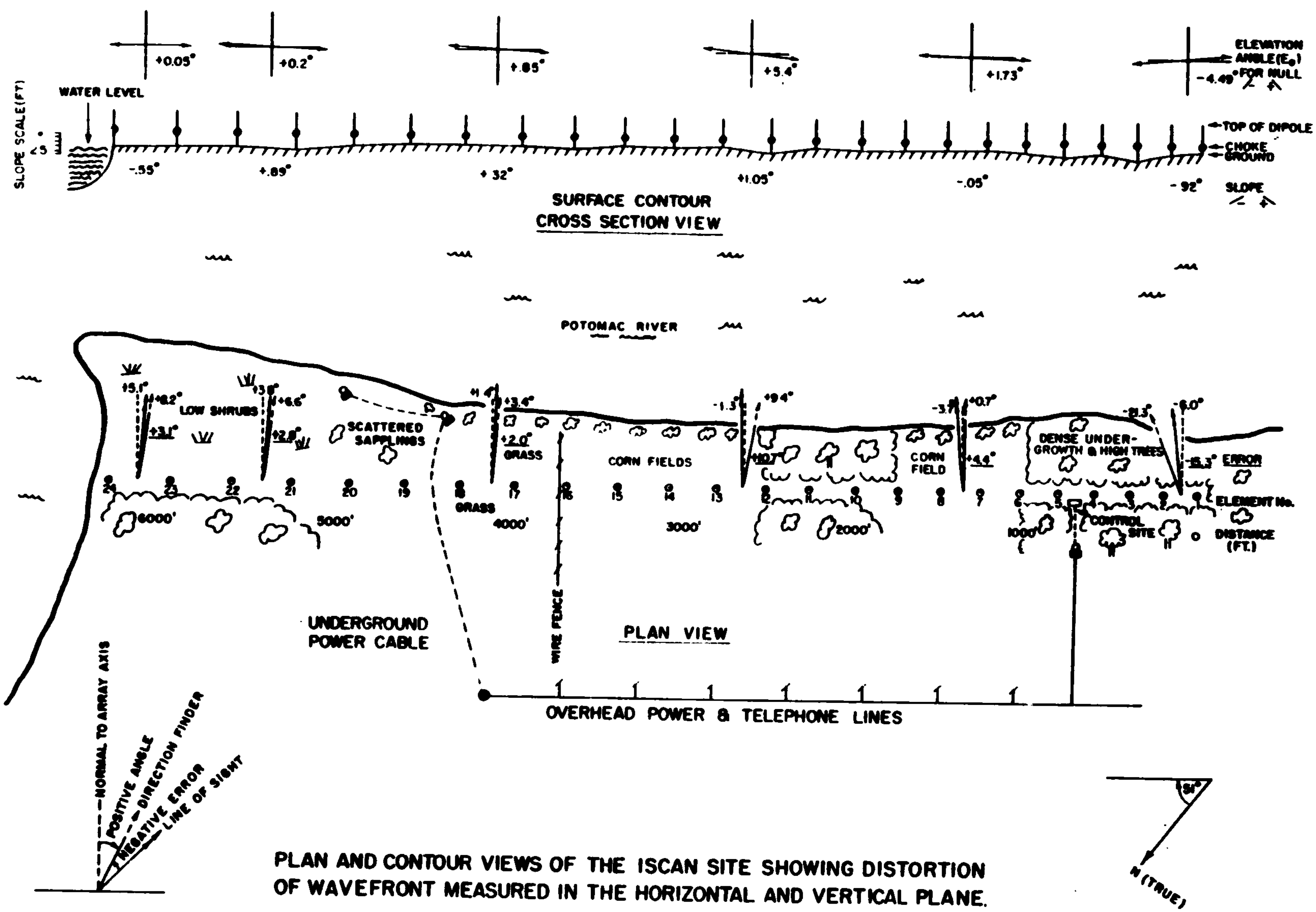
REFERENCES

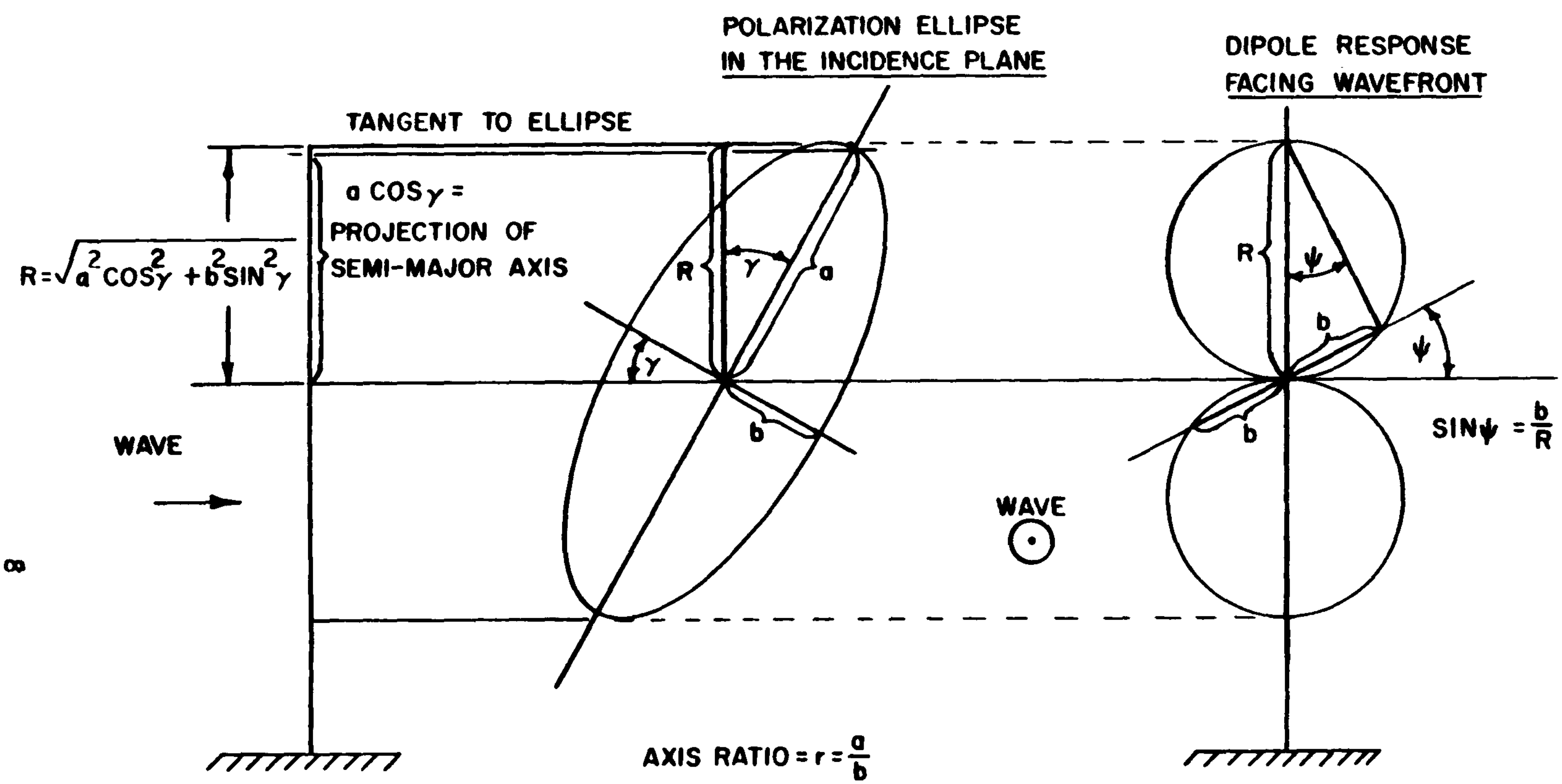
1. "Final Report,"30 Oct 54, File No. 13331-PH-53-91(4106), Contract No. DA36-039 SC-42709, Kollsman Instrument Company.

2. "Uber die Messung der Bodenleitfahigkeit," J. Grosskopf and K. Vogt, Telegraphen-, Funk- and Fernsprech-Technik, Vol 29, No. 6 (1940), p. 164.



PLAN AND CONTOUR VIEWS OF THE ISCAN SITE SHOWING DISTORTION OF WAVEFRONT MEASURED IN THE HORIZONTAL AND VERTICAL PLANE.

FIGURE I



$$r=\frac{\sqrt{1-\sin^2\gamma\,\sin^2\psi}}{\sin\psi\,\cos\gamma}$$

THE EVALUATION OF THE AXIS RATIO FROM ψ AND γ

FIGURE 2

Location No.	Time	Location Between Elements	Tilt angle of Minor Axis γ^o	Elevation Angle ϕ^o	Tilt angle of Major Axis τ^o	Axis Ratio r	Ratio of Horizontal & Vertical width $\lvert\rho\rvert$	Phase Angle φ^o	Dielectric Constant ε (esu)	Conductivity σ (esu)	σ (emu)
1	1000 to 1035	1 and 2	14	5.0	76	11.9	.262	18.7	11.6	6.7×10^7	7.45×10^{-14}
2	1115 to 1150	23 and 24	8.15	7.35	81.9	7.9	.187	41.7	3.23	21.4×10^7	23.8×10^{-14}
3	1205 to 1237	21 and 22	8.45	8.30	81.6	7.0	.203	45.7	0	18.4×10^7	20.5×10^{-14}
4	1305 to 1330	17 and 18	12.9	5.15	77.2	11.4	.247	22.6	11.55	8.8×10^7	9.77×10^{-14}
5	1400 to 1428	12 and 13	19.5	5.63	70.5	10.8	.364	16.6	6.35	3.14×10^7	3.48×10^{-14}
6	1450 to 1520	7 and 8	17.0	7.45	73	8.07	.305	24.4	6.05	5.3×10^7	5.9×10^{-14}
10	1605 to 1700	1 and 2	13.8	5.40	76.3	10.9	.256	22.2	11.0	8.1×10^7	9.0×10^{-14}

TABLE 1. Results of Measurements of Axis Ratio and Tilt Angle at Various Locations Along the Array Axis

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